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ROSAT

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TABLE OF CONTENTS

SUMMARY

During the period 1 July 1997 through 30 June 1998, one paper using *ROSAT* data, supported in part by this grant, NAG 5-4789, was published in a refereed journal, and one AAS paper was presented. Their bibliographical references are listed in the Appendix, and the abstracts of these papers are given in the next two sections of this report. In addition, summaries of the work in progress on the two most recent projects are given in the subsequent sections.

1. X-ray Emission from the Millisecond Pulsar J1012+5307

J. P. HALPERN AND F. Y.-H. WANG

ABSTRACT

The recently discovered 5.3 ms pulsar J1012+5307 at a distance of 520 pc is in an area of the sky which is particularly deficient in absorbing gas. The column density along the line of sight is less than 7.5×10^{19} cm^{-2}, which facilitates soft X-ray observations. Halpern (1996, ApJ, 459, L9) reported a possible *ROSAT* PSPC detection of the pulsar in a serendipitous, off-axis observation. We have now confirmed the X-ray emission of PSR J1012+5307 in a 23 ksec observation with the *ROSAT* HRI. A point source is detected within 3$''$ of the radio position. Its count rate of $1.6 \pm 0.3 \times 10^{-3}$ s^{-1} corresponds to an unabsorbed 0.1–2.4 keV flux of 6.4×10^{-14} ergs cm^{-2} s^{-1}, similar to that reported previously. This counts-to-flux conversion is valid for $N_{\rm H} = 5 \times 10^{19}$ cm^{-2}, and either a power-law spectrum of photon index 2.5 or a blackbody of $kT = 0.1$ keV. The implied X-ray luminosity of 2.0×10^{30} ergs s^{-1} is 5×10^{-4} of the pulsar's spin-down power $\dot{E}$, and similar to that of the nearest millisecond pulsar J0437–4715, which is nearly a twin of J1012+5307 in P and $\dot{E}$. We subjected the 37 photons (and 13 background counts) within the source region to a pulsar search, but no evidence for pulsation was found. The pulsar apparently emits over a large fraction of its rotation cycle, and the absence of sharp modulation can be taken as evidence for surface thermal emission, as is favored for PSR J0437–4715 (Zavlin & Pavlov 1997, A&A, in press), rather than magnetospheric X-ray emission which is apparent in the sharp pulses of the much more energetic millisecond pulsar B1821–24 (Saito et al. 1997, ApJ, 477, L37). A further test of this interpretation will be made with a longer *ROSAT* observation, which will increase the number of photons collected by a factor of 5, and permit a more sensitive examination of the light curve for modulation due to emission from heated polar caps. If found, such modulation will be

further evidence that surface reheating by the impact of particles accelerated along open field lines operates in these $\sim 10^9$ yr old pulsars.

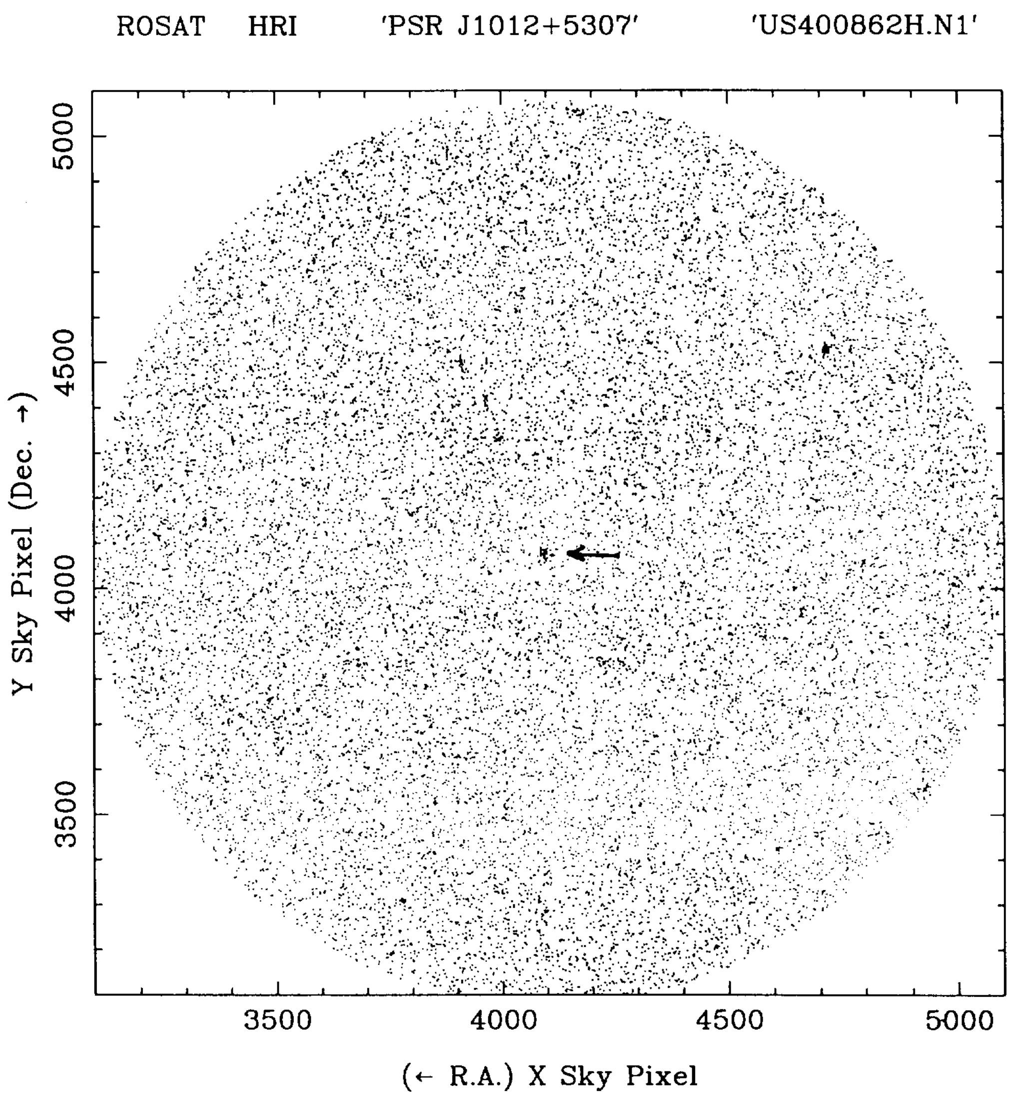

FIG. 1. – *ROSAT* HRI pointed observation of PSR J1012+5307.

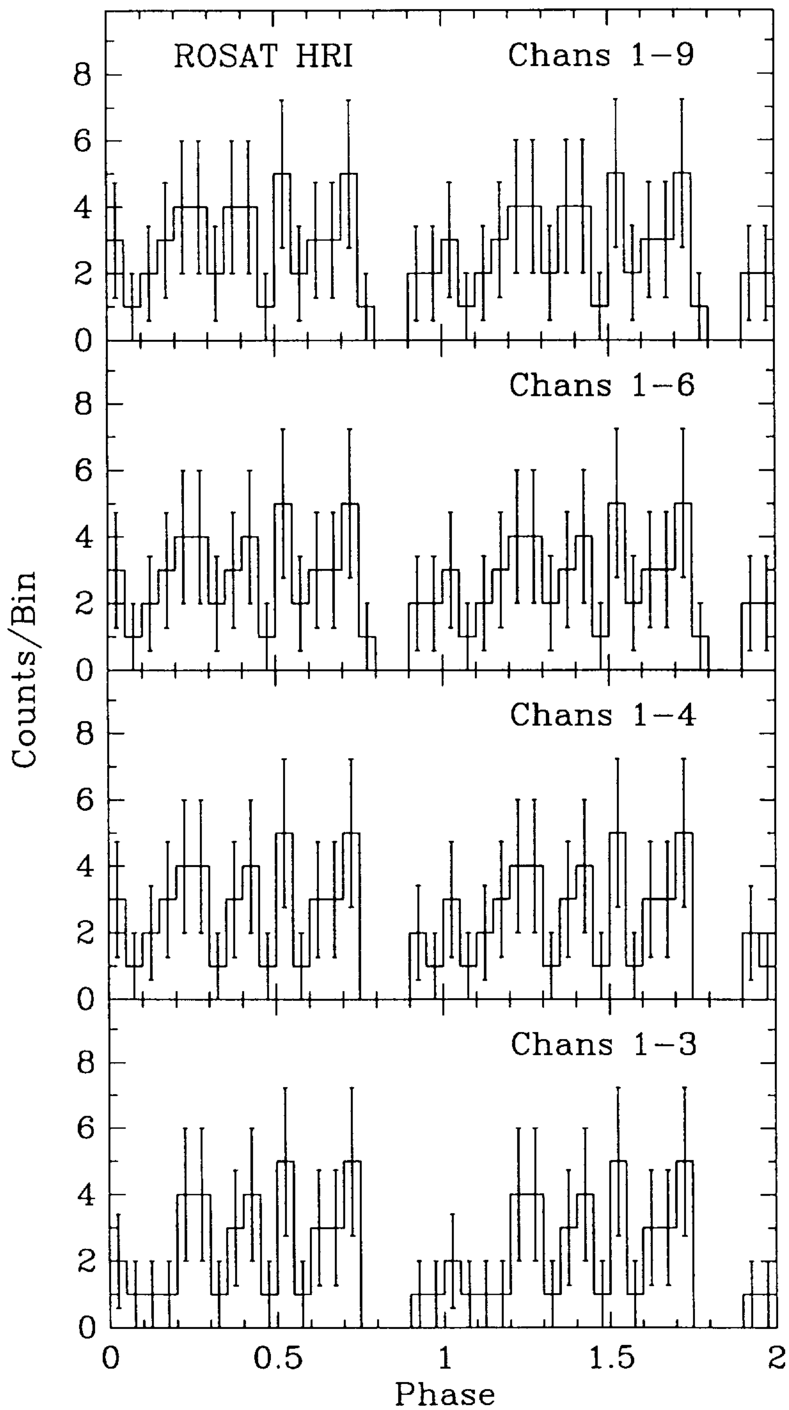

FIG. 2. – Folded light curve of PSR J1012+5307 in the *ROSAT* HRI.

2. EUVE J0425.6–5714: A Newly Discovered AM Herculis Star

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ABSTRACT

We detected a new AM Her star serendipitously in a 25 day observation with the *EUVE* satellite. A coherent period of 85.82 min is present in the *EUVE* Deep Survey imager light curve of this source. A spectroscopic optical identification is made with a 19th magnitude blue star that has H and He emission lines, and broad cyclotron humps typical of a magnetic cataclysmic variable. A lower limit to the polar magnetic field of 50 MG is estimated from the spacing of the cyclotron harmonics. EUVE J0425.6–5714 is also detected in archival *ROSAT* HRI observations spanning two months, and its stable and highly structured light curve permits us to fit a coherent ephemeris linking the *ROSAT* and *EUVE* data over a 1.3 yr gap. The derived period is 85.82107 ± 0.00020 min, and the ephemeris should be accurate to 0.1 cycles until the year 2005. A narrow but partial X-ray eclipse suggests that this object belongs to the group of AM Her stars whose viewing geometry is such that the accretion stream periodically occults the soft X-ray emitting

accretion spot on the surface of the white dwarf. A non-detection of hard X-rays from *ASCA* observations that are contemporaneous with the *ROSAT* HRI shows that the soft X-rays must dominate by at least an order of magnitude, which is consistent with a known trend among AM Her stars with large magnetic field.

This object should not be confused with the Seyfert galaxy 1H 0419–577 (= LB 1727), another X-ray/EUV source which lies only 3.′95 away, and was the principal target of these monitoring observations.

Subject headings: cataclysmic variables — stars: individual (EUVE J0425.6–5714) — X-rays

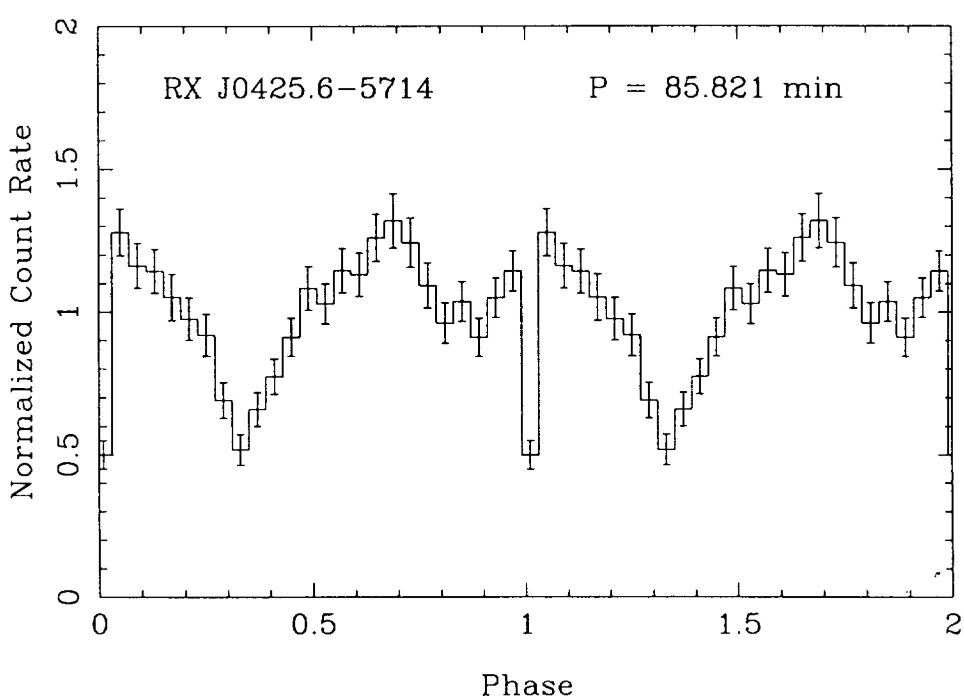


FIG. 3. – Folded light curve of the AM Her star EUVE J0425.6–5714 in the *ROSAT* HRI observations of 1996. Background has been subtracted. Phase 0 correspond to HJD 2450264.5651.

3. Identification of Persistent EGRET Sources at Intermediate Galactic Latitude

The identity of the persistent high-energy (> 100 MeV) γ-ray sources in the Galaxy is still largely a mystery. The second installment of the EGRET (2EG) (Thompson et al. 1995) lists a total of 128 sources, of which 51 are likely or possibly identified with AGNs (Montigny et al. 1995), five with rotation-powered pulsars (Thompson et al. 1994), and one is the LMC (Sreekumar et al. 1992). There are 71 unidentified sources, of which 33, or almost half, lie in the narrow band of $|b| \leq 10^\circ$ along the Galactic plane. This excess of low-latitude sources must, therefore, constitute a Galactic population that is either similar to the already identified γ-ray pulsars, or an entirely new class of γ-ray emitters associated with the disk population. We are continuing our program, begun in AO6, that is aimed at intermediate-latitude sources, arguing that X-ray detection of them is the most plausible method of identifying the Galactic population. The sources at high latitude must statistically be mostly AGNs, and are more straightforwardly identified through radio and optical means.

The Galactic sources will be difficult to identify. We first describe the observational and theoretical constraints that affect the ability of ROSAT to make an identification of any particular EGRET source. We then describe the choice of targets for which ROSAT is optimally suited, and argue that if they have X-ray properties like any of the already identified sources, then we expect to identify them through follow-up optical and radio observations of HRI sources detected in their γ-ray error circles. Indeed, X-ray detection may be the *only* means of identifying the majority of EGRET Galactic sources if, as many think, they are pulsars that are radio quiet, or whose narrow radio beams do not cross the earth.

Rotation-powered pulsars seem most likely to explain the Galactic γ-ray source population. The shapes of radio pulsar beams as determined by the highly successful rotating vector model (Radhakrishnan & Cooke 1969) demand that the majority, $\sim 70\%$ of young radio pulsars, are *not* visible from Earth. The clear differences between the broad γ-ray beam patterns and the narrow radio pulses implies that γ-ray emission is probably visible from a much wider range of directions than are the radio beams. Indeed, the ROSAT identification of the high-energy γ-ray source Geminga as the first radio quiet, but otherwise ordinary pulsar (Halpern & Holt 1992), provides what might be the prototype for the remaining unidentified Galactic sources. Nearly all predictions of the γ-ray pulsar population begin with the understanding that radio detection of most γ-ray pulsars is not a necessary or even an expected occurrence, although a few more radio pulsars may be responsible for EGRET sources that have too few γ-ray photons to reveal their corresponding periods.

Several authors have considered the pulsar hypothesis from statistical or theoretical points of view. Beginning with the properties of the identified EGRET pulsars, Halpern & Ruderman (1993) parameterized the observed increase of γ-ray efficiency η with age as $\eta = 0.2\,\tau_5$, where τ_5 is the age in units of 10^5 yr. Using the estimated birth rate of pulsars in the solar neighborhood, they estimated that approximately 23 γ-ray pulsars should be visible to a threshold of 3×10^{-10} ergs cm^{-2} s^{-1}, and that the typical distance would be ~ 1.5 kpc for an assumed scale height of 3°. This total number of 23 would be reduced by any beaming factor that prevents detection through a full 4π steradians. One of the interesting consequences of this scenario is that most pulsars manage to maintain a roughly constant γ-ray luminosity of $\sim 3 \times 10^{34}$ ergs s^{-1} while spinning down, until the efficiency of this process approaches unity. Indeed, Table 1, in which the pulsars are ordered according to decreasing spin-down power $I\Omega\dot{\Omega}$, clearly shows the corresponding increase in γ-ray efficiency.

The most detailed theoretical treatment of the pulsar model for the Galactic γ-ray sources is that of Romani & Yadigaroglu (1995) and Yadigaroglu & Romani (1995). They developed a numerical calculation of γ-ray production and beaming in the outer-gap model that successfully reproduces the basic observed features of the pulse profiles and the γ-ray efficiency as a function of age. By combining this model with a Monte Carlo simulation of the Galactic pulsar population, they estimated that a total of 22 pulsars should be detected by EGRET at the same flux threshold as was adopted by Halpern & Ruderman (1993), which also approximates the threshold of the first EGRET catalog. This number is remarkably close to the earlier back-of-the-envelope calculation, and to the actual number of EGRET sources. A further result of this simulation is that the mean distance to unidentified γ-ray pulsars should decrease from 3.5 to less than 1 kpc as the age increases from 10^4 to 10^6 yr. Most pulsars are old, of course, and therefore nearby.

If we adopt these pulsar scenarios as the most likely description of the Galactic γ-ray source population, then we should look at the soft X-ray properties of Geminga and the other older pulsars as a guide to planning ROSAT identifications. All of these were detected by ROSAT, with some combination of nonthermal emission, and thermal emission from the surface of the neutron star. The latter is the hallmark of all the older pulsars, with surface temperatures ranging from 5×10^5 K in Geminga (Halpern & Ruderman 1993) and 7×10^5 K in PSR 1055–52 (Ögelman & Finley 1993), to 1.5×10^6 K in Vela (Ögelman, Finley, & Zimmermann 1993). Since most of the γ-ray pulsars are likely to fall in this older age range, we should base our target selection and exposure times on the feasibility of detecting thermal emission, which is the only significant source of X-rays in older pulsars. In fact, there is some evidence that in γ-ray pulsars, the accelerator is responsible for reheating the surface of the neutron star when particles strike the surface (Halpern & Ruderman 1993). PSR 1055–52 is hotter than expected for its age from the standard cooling curves. The X-rays and γ-rays may together sustain the accelerator through pair production. Thus the close association between soft X-ray detected pulsars and high-energy γ-ray sources.

Our basic strategy is to map the error circles of the EGRET sources, looking for sources that may be identified with neutron stars either through their pointlike, thermal emission, or possibly a compact synchrotron nebula in the case of a younger pulsar. Since the HRI does not have the throughput in most cases to detect enough photons to discover a period, the identification of the X-ray source with a neutron star will depend primarily on follow-up optical observations to establish the nature (or absence!) of a faint optical counterpart, or possibly a search for a faint radio pulsar counterpart.

For a number of reasons, we can optimize our chances of success by choosing three targets that are found at "intermediate" Galactic latitudes. $3^\circ < |b| < 20^\circ$, and that are not apparently variable. The advantage of this choice is that it increases the likelihood that (*a*) the source is real, (*b*) its position is not affected by errors in the diffuse emission model or nearby weak sources, (*c*) it is nearby, (*d*) the column density is not too high, and (*e*) the corresponding optical fields are not too crowded. The absence of variability is important, since the known γ-ray pulsars show little if any change, while the AGNs are often dramatically variable.

The height above the Galactic plane at which a pulsar will be found is determined by its birth in a young stellar population with scale height ~ 80 pc. and the high velocity which will carry it away from the plane with a mean z-component of 260 km s^{-1} (newly determined by Lyne & Lorimer 1994). Thus, after a time of 10^5 yr, the average pulsar will be found at a height of ~ 100 pc, and after 10^6 yr, at ~ 350 pc. Since both observation and theory say that γ-ray pulsars will be detectable in this age range and at a typical distance of 1–1.5 kpc, the corresponding angular distance from the plane for these typical values is $4^\circ - 20^\circ$, which accounts for our Galactic latitude selection. Older pulsars will have even a larger height and a smaller distance, and Mukherjee et al. (1995) showed that there is statistical evidence for some of them at higher latitudes.

In AO6, we were given 3 targets at Galactic latitudes $3^\circ < |b| < 8^\circ$, and encouraged to continue this program in future AOs. Each of these fields was covered with four overlapping HRI pointings. The HRI has a $38'$ square field. Four pointings whose centers are separated by $27'$, cover a $54'$ diameter that includes the entire 95% error ellipse in each case. For each of these three fields, we also obtained VLA observations on March 31, 1996 to help in the identification of the X-ray sources, and to look for plausible pulsar candidates. We designed the VLA observing program to be sensitive to pulsars by concentrating on low-frequency, 327 MHz mapping. Pulsars are steep-spectrum sources, and could be identified by comparison of our 327 MHz and 1490 MHz maps. The analysis of 327 MHz data is difficult, and has only just begun.

We have carried out optical imaging and spectroscopic observations of approximately 26 HRI sources in these three fields over the past year, using telescopes at Kitt Peak National Observatory and the MDM Observatory. While most are M stars or other bright stars, there are still one or two possibly unidentified sources which therefore remain as γ-ray source candidates.

We were assigned two additional EGRET source fields in AO7, but we have only just begun to receive some of these data, which were originally processed with an incorrect boresight that prevented optical identifications from being made while wasting much optical telescope time. We will soon request VLA observations of the one northern field, 2EG J1635-1427, as we did for our three fields from AO6. The VLA observations are designed to permit the detection of pulsar candidates by looking for steep-spectrum sources, those that are bright at 327 MHz relative to 1490 MHz.

This proposal focussed on the properties of pulsars, because that scenario is the one most dependent upon X-ray searches for identification, and the one with the most stringent requirements on the feasibility. But what if the counterpart is not a pulsar? Although none of these sources has a plausible blazar counterpart (Mattox et al. 1996), it cannot be excluded that an errant blazar will be lurking behind the Galactic plane. ROSAT is ideally suited to discovering a new type of γ-ray AGN, the long-hypothesized "radio-quiet blazar". Other types of Galactic counterparts are much rarer, but easier to identify. The Gregory-Taylor binary LSI +61°303 as a possible counterpart of 2CG 135+01 is a serious example, as is Cygnus X-3 for 2EG J2033+4112. These are bright X-ray sources, well detected by *Einstein* and ROSAT. Optical and radio follow-up observations of ROSAT sources will likely be necessary to support the identification process.

4. A Possible Identification For The EGRET Source 2EG J2227+6122

J. P. HALPERN AND D. J. HELFAND

ABSTRACT

The identity of the persistent, high-energy gamma-ray sources in the Galactic plane is a mystery. The most likely scenario is a population of middle-aged pulsars, many of which could be radio quiet like Geminga. We have an ongoing program of *ROSAT*, VLA, and optical observations of selected EGRET error circles at intermediate Galactic latitude. For one of these fields, at $(\ell, b) = (106^\circ, +3^\circ)$, our complete census of X-ray and radio sources reveals a remarkable association between a radio shell with unique properties, and a compact X-ray source. Further observations are needed to determine whether or not this source has a hard X-ray spectrum like that of other γ-ray pulsars and, ideally, to find its pulsations.

Background

The identity of the persistent high-energy (> 100 MeV) γ-ray sources in the Galaxy is still largely a mystery. The second installment of the EGRET catalog (Thompson et al. 1995) lists a total of 128 sources, of which 51 are likely or possibly identified with AGNs, five with rotation-powered pulsars, and one is the LMC. There are 71 unidentified sources, of which 33, or almost half, lie in the narrow band of $|b| \leq 10^\circ$ along the Galactic plane. This excess of low-latitude sources must, therefore, constitute a Galactic population that is either similar to the already identified γ-ray pulsars, or an entirely new class of γ-ray emitters associated with the disk population. These Galactic sources have proven extremely difficult to identify. We have an ongoing program to search for plausible candidates by a variety of techniques, in a specially selected subset of EGRET fields that we judge may be less resistant to identification than the majority of the Galactic plane sources. This report offers the possible culmination of one of those searches, in that we have obtained complete radio, optical, and X-ray coverage of an EGRET error box that points to an unusual association that might be a pulsar with a wind-blown nebula.

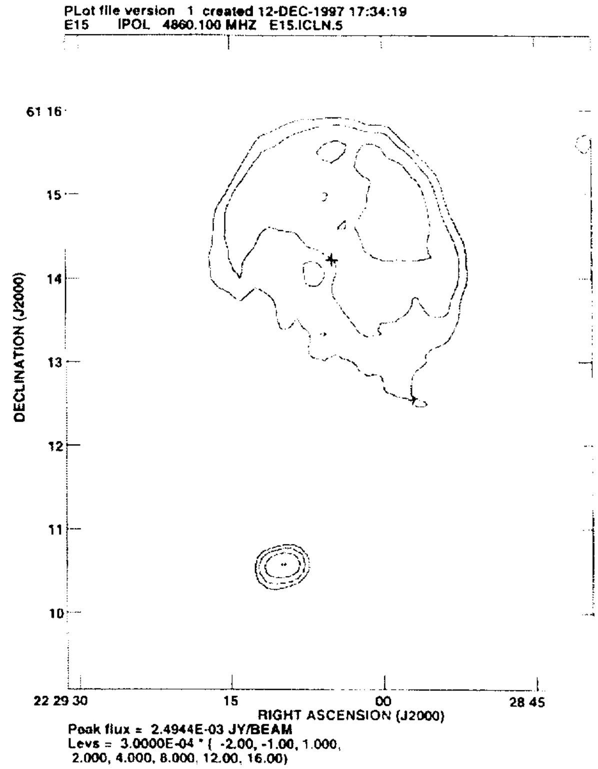
Adopting such a pulsar scenario as the motivating hypothesis for an observational search, we began with *ROSAT* HRI observations of three bright EGRET sources that are at "intermediate" Galactic latitudes, $3° < |b| < 8°$, and that are not apparently variable: 2EG J0323+5126, 2EG J0521+2206, and 2EG J2227+6122. A total of 24 X-ray sources were detected in these three EGRET fields, and we have obtained secure imaging and spectroscopic identifications for 21 of them using telescopes on Kitt Peak. Twenty of these are coronal emitters, i.e., ordinary stars of late spectral type, and one is a pre-main sequence Ae star. Of the three remaining HRI sources with ambiguous IDs, one is coincident with a 40 mJy compact radio source which has a faint optical counterpart, so it may be a distant quasar or blazar. It is not possible to establish whether such a weak radio AGN is the EGRET identification. Another X-ray source is coincident with a 20th magnitude, radio-quiet object for which we have not yet been able to obtain a spectrum; it may well also be a background quasar.

Results

The final ambiguous X-ray source is the subject of this report. It is the only unidentified X-ray source (out of six) in the field of 2EG J2227+6122, and it lies at the center of an incomplete shell of radio emission of diameter $\approx 3'$, which itself is the most unusual radio source that is present in all of our VLA maps. Figure 4 shows a 6 cm VLA map with the position of the HRI source superposed as a cross. Several anomalous properties of this radio shell prevent us from deriving a consistent physical theory of its nature, but its likely association with a compact X-ray source makes it an important candidate for identification with the EGRET source.

The limb-brightened radio shell most resembles a small-diameter supernova remnant (as opposed to a Galactic H II region or radio galaxy), but we are not able to reconcile

FIG. 4. – A 6 cm radio map of the new shell-like radio source in the error box of 2EG J2227+6122. The cross near its center marks the location of a *ROSAT* HRI source. The pointlike radio source below the shell has a steep spectrum, and is presumably a background AGN.



its morphological characteristics with its radio spectrum. We obtained both 20 cm and 6 cm maps at the same spatial resolution, with the surprising result that the spectrum is approximately flat. The integrated fluxes are $\sim$ 70 mJy at 20 cm and $\sim$ 90 mJy at 6 cm. Such a flat spectrum, $\alpha = 0.2 \pm 0.1$, is more like that of thermal bremsstrahlung than the usual $\alpha = -0.7$ which characterizes the radio synchrotron emission of shell-like remnants. However, if we interpret the radio source as thermal emission from an H II region, we are lacking the usual evidence of the exciting star(s). Our optical images show no bright, blue stars, no nebulosity, and deep Hα images that we have obtained show no diffuse line emission anywhere near this source. Could this be due simply to the significant optical extinction in this direction? The Galactic coordinates of this source are $(\ell, b) = (106.^\circ65, +2.^\circ95)$, and the total 21 cm column density along the line of sight is 9.6×10^{21} cm^{-2}, corresponding to as much as 5 magnitudes of extinction at Hα. Nevertheless, it is unlikely that an H II region of this size and brightness could be rendered entirely invisible. In fact, there is another comparably sized, diffuse radio source in this EGRET field that is associated with Sharpless 141, an H II region that is prominent on the Palomar Sky Survey plates. And the morphology of our radio shell is unlike that of most H II regions. So none of the standard radio source interpretations fit for this object. Turning now to the X-ray source, it is approximately centered on the radio shell, and it has no optical counterpart. The nearest star, approximately $7''$ away, appears to be a moderately reddened A star of 18th magnitude, a most unlikely identification. No other stars are in its error circle to the limit of the Palomar Sky Survey.

Given the striking positional coincidence, it is both highly likely that X-ray and radio sources are related, and reasonable to hypothesize that the this unique object is a strong candidate for the EGRET source ID. The next step is to examine the pulsar hypothesis in the light of the known X-ray properties of γ-ray pulsars, and to test it using the hard X-ray sensitivity of *ASCA*. All of the pulsars detected by EGRET are also detected by *ROSAT* and *ASCA*, as a consequence of some combination of nonthermal emission and thermal emission from the surface of the neutron star. The latter is the hallmark of middle-aged pulsars, with surface temperatures ranging from 5×10^5 K in Geminga (Halpern & Ruderman 1993) and 7×10^5 K in PSR 1055–52 (Ögelman & Finley 1993), to 1.5×10^6 K in Vela (Ögelman, Finley, & Zimmermann 1993). The younger EGRET pulsars, including Vela and PSR B1706–44 (Finley et al. 1998), are mainly nonthermal X-ray sources, with a dominant contribution from a compact synchrotron nebula. From the *ROSAT* HRI data alone, it is not possible to decide whether the X-rays from our candidate are thermal or nonthermal. Its count rate of 2.5×10^{-3} s^{-1} is consistent with a range of thermal temperatures between 5×10^5 K and 1.3×10^6 K for a 10 km radius neutron star at 1.5 kpc, a distance which is typical for the EGRET Galactic source population from the statistical studies discussed above. But the HRI detected count rate is also highly affected by the interstellar column density, such that $N_{\rm H}$ would have to range from a mere 10^{20} cm^{-2} for $T = 5 \times 10^5$ K, to 1×10^{22} cm^{-2} for $T = 1.3 \times 10^6$ K. The true column density is undoubtedly somewhere between these extremes.

Although these thermal spectra would extrapolate to very weak sources in *ASCA*, it is more likely that the hard X-rays from a γ-ray pulsar would be dominated by a synchrotron power law. The *ASCA* spectrum of Geminga is best fitted by a power-law of photon index $\Gamma = 1.5$. Further evidence that Geminga's hard X-rays are nonthermal comes from their pulse shape, which is sharp and double-peaked, with pulsed fraction $\approx 55\%$. In contrast, the soft X-rays have a single broad peak with pulsed fraction $20 - 30\%$, and they are not in phase with the harder X-rays. A hard X-ray power-law component with $\Gamma \simeq 1.5$ and large pulsed fraction was also detected by *ROSAT* and *ASCA* from another γ-ray pulsar, PSR B1055–52 (Ögelman & Finley 1993; Wang et al. 1998). If the $\Gamma = 1.5$ power law proves to be universal for γ-ray pulsars, then this hard X-ray signature may be an excellent means of finding the pulsars that are suspected to be responsible for many of the unidentified EGRET sources.

A general theory of X-ray emission from rotation-powered pulsars has been developed (Wang et al. 1998) which predicts that any strong γ-ray pulsar will have a hard X-ray spectrum with photon index $\Gamma = 1.5$. In this model, an outer-gap accelerator will send $e^{\pm}$ pairs flowing inward and outward along open magnetic field lines. These particles continuously radiate γ-rays by the curvature mechanism. When the inward flowing particles approach the surface of the star, the > 100 MeV γ-rays that they emit convert into secondary $e^{\pm}$ pairs in the inner magnetosphere wherever $B\sin\phi > 2 \times 10^{10}$ G, where ϕ is the angle between the photon and the $\mathbf{B}$ field. Those secondary pairs must radiate away their energy instantaneously in the strong local $\mathbf{B}$ field. Such a synchrotron decay spectrum has $\Gamma = 1.5$ between $E_{\rm min} = 0.2$ keV and $E_{\rm max} = 5$ MeV. We emphasize that in this theory, the X-ray power-law is *not* supposed to be a simple continuation of the EGRET spectrum. Rather, it is a separate component radiated by the secondary $e^{\pm}$ pairs that are created when some of the primary γ-rays convert in the strong $\mathbf{B}$ field.

5. Wasilewski 49: Mirror for a Hidden Seyfert 1 Nucleus

Wasilewski 49 is an interacting pair of Seyfert galaxies at $z = 0.063$, one of which contains a hidden Seyfert 1 nucleus as evidenced by broad wings on its Balmer lines. The disk of the main galaxy appears to be globally photoionized by a powerful continuum source, apparently the hidden Seyfert 1 nucleus of its companion. A *ROSAT* HRI observation of this pair, separated by $7''$, was made to detect the ionizing continuum, and to determine what fraction of the X-rays are coming from a point source. A point source was detected at the position of the hidden Seyfert 1 nucleus, as expected. We made optical identifications of at least three additional HRI sources in this field in order to verify the pointing. This reduces the error in absolute position to less than $2''$, and confirms our model of the system. The detected X-ray flux was about a factor of 5 less than expected, but consistent with a crude estimate based on the number of ionizing photons needed to account for the broad Hα emission line wings, assuming that both the soft X-rays and the broad Hα flux are seen via energy-independent electron scattering (the NGC 1068 model).

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APPENDIX

Papers Published Under NASA Grant NAG 5-4789

During the Period 1 July 1997 - 30 June 1998

1. "X-ray Emission from the Millisecond Pulsar J1012+5307", J. P. Halpern, & F. Y.-H. Wang, *B.A.A.S.*, **29**, 1391 (1997).
2. "EUVE J0425.6–5714: A Newly Discovered AM Herculis Star," J. P. Halpern, K. M. Leighly, H. L. Marshall, M. Eracleous, & T. Storchi-Bergmann, *P.A.S.P.*, **110**, 1394 (1998).